WATER QUALITY

Characterization

Water quality standards are determined for each water body by the Oregon Department of Environmental Quality (ODEQ). These standards are designed to protect each water body for its most sensitive beneficial use (Miner *et al*. 1996, p. 1). The beneficial uses depending on aquatic resources in the analysis area, and the water quality parameters affecting those beneficial uses are displayed in Table WC-1.

Table WC-1: Beneficial Uses and Associated Parameters for Streams in the North Fork Coquille Watershed

Parameters:	Beneficial Uses:													
	public domestic water supply	private domestic water supply	industrial water supply	irrigation	livestock watering	anadromous fish passage	salmonid fish rearing	salmonid fish spawning	resident fish, other aquatic life	wildlife and hunting	fishing	boating	water contact recreation	aesthetic quality
Aquatic Weeds or Algae											X		X	
Bacteria													X	
Biological Criteria									X					
Chlorophyll a	X	X	X		X						X		X	X
Dissolved Oxygen							X	X	X					
Habitat Modification							X	X	X					
Flow Modification							X	X	X					
Nutrients											X		X	X
pH									X				X	
Sedimentation							X	X	X					
Temperature							X	X	X					
Total dissolved gas									X					
Toxics									X					
Turbidity	X	X	X						X					X

The sources for beneficial uses: Table 3-W-1 in the Draft Coos Bay District Resource Management Plan and Environmental Impact Statement (USDI 1992), and http://waterquality.deq.state.or.us/wq/wqrules/340Div41Tbl4.pdf
The source for parameters: http://waterquality.deq.state.or.us/WQLData/ListingCriteria.htm (ODEQ 1998a)

Current Conditions

ODEQ tracks water quality using the Water Quality Limited Streams Database. This database can be viewed on the internet at: http://waterquality.deq.state.or.us/wq/303dlist/303dpage.htm [1](ODEQ 1998b). The criteria for classifying a reach water quality limited and data requirements can also be viewed on the internet at: http://waterquality.deq.state.or.us/WQLData/ListingCriteria.htm (ODEQ 1998a). The Water

[1] At the Water Quality Limited Streams page, click on "Review the final 1998 303(d) database" then click on "Search 303d database from map of Oregon", click on "Coquille."

Quality Appendix contains tables that present water quality data by parameter, from ODEQ's database, for the North Fork Coquille Watershed. The following table summarizes that water quality data.

WQ-2: North fork Coquille Stream Reaches Listed in ODEQ's Water Quality Limited Streams Database

ID	Water body Name	Boundaries	Parameter	Listing Status
4991	Alder Ck.	Mouth to headwaters	Temperature	303(d) List
4628	Cherry Ck.	Mouth to Little Cherry Ck.	Temperature	303(d) List
5001	Cherry Ck.	Little Cherry Ck. to Headwaters	Temperature	Meets Standards
4641	Evans Ck.	Mouth to Headwaters	Temperature	Meets Standards
4643	Giles Ck.	Mouth to Headwaters	Temperature	Meets Standards
4646	Johns Ck.	Mouth to Headwaters	Temperature	Meets Standards
4635	Little No. Fk. Coquille	Mouth to Headwaters	Temperature	Potential Concern
4996	Middle Ck.	Mouth to headwaters	Temperature	303(d) List
5012	No. Fk. Cherry Ck.	Mouth to Little Cherry	Temperature	Meets Standards
4633	No. Fk. Coquille	Mouth to Middle Ck.	Temperature	303(d) List
4634	No. Fk. Coquille	Middle Ck. to Little No. Fk.	Temperature	303(d) List
5007	No. Fk. Coquille	Little No. Fk. to headwaters	Temperature	Meets Standards
4997	Park Ck.	Mouth to Headwaters	Temperature	Meets Standards
5000	Woodward Ck.	Mouth to headwaters	Temperature	303(d) List
4855	No. Fk. Coquille	Mouth to Middle Ck.	Sedimentation	Need Data
4856	No. Fk. Coquille	Middle Ck. to Headwaters	Sedimentation	Need Data
4973	No. Fk. Coquille	Mouth to Middle Ck.	Dissolved Oxygen: May 1 - Sept. 30	TMDL Approved
4734	No. Fk. Coquille	Mouth to Middle Ck.	Dissolved Oxygen: Oct. 1- Apr. 30	Meets Standards
4771	No. Fk. Coquille	Mouth to Middle Ck.	Habitat Modification	Need Data
4772	No. Fk. Coquille	Middle Ck. to Headwaters	Habitat Modification	Need Data
4780	Moon Ck.	Mouth to Headwaters	Habitat Modification	Need Data
4896	No. Fk. Coquille	Mouth to Middle Ck.	Flow Modification	Need Data
4817	No. Fk. Coquille	Mouth to Middle Ck.	pH: fall-winter-spring seasons	Meets Standards
4911	No. Fk. Coquille	Mouth to Middle Ck.	pH: summer season	Meets Standards
4912	No. Fk. Coquille	Mouth to Middle Ck.	Nutrients	Need Data
4810	No. Fk. Coquille	Middle Ck. to Headwaters	Nutrients	Need Data
4809	No. Fk. Coquille	Mouth to Middle Ck.	Chlorophyll a	Meets Standards
4715	No. Fk. Coquille	Mouth to Middle Ck.	Bacteria: fall-winter-spring seasons	303(d) List
4716	No. Fk. Coquille	Mouth to Middle Ck.	Bacteria: summer season	Meets Standards

Water bodies that do not meet water quality standards are placed on the states' 303(d) list as Water Quality Limited (ODEQ 1998). High water temperatures and elevated fine sediment levels are the primary non-point source pollutants of surface water in the Watershed (ODEQ 1988). Both high temperatures and excessive sedimentation can cause impacts on aquatic life, particularly fish and invertebrate reproduction. The 1998 303(d) list designates reaches of the North Fork Coquille River and four of its tributaries as water quality limited. Table WQ-3 gives the boundaries and listing parameters for the water quality limited reaches.

The Oregon Department of Environmental Quality identified the Coquille River as potentially water quality limited as early as 1973, and confirmed it as a "Waterbody of Concern" in the 1988 Water

Quality Report, and in subsequent reports (ODEQ 1988).

There is no known point source water pollution in the watershed at this time. A suspected point source, however, is at the old Fairview landfill on BLM land in section 27, T.27S., R.12W. Currently, tests are being conducted by the BLM to determine what types and concentrations of these suspected contaminants and their potential impacts are leaching from the site.

Table WQ-3: 1998 303(d) Listed Waterbodies in the North Fork Coquille Watershed

Water body	Boundaries	Parameter & Criteria	Supporting Data
Alder Creek	Mouth to headwaters	Temperature Rearing 64°F (17.8°C) summer	1996 data show exceedence of temperature criteria, 7 day ave. max. 65.7°F, 1997 data do not show an exceedence of 7 day ave. max. was 63.9°F.
Cherry Creek	Mouth to Little Cherry Creek	Temperature Rearing 64°F (17.8°C) summer	DEQ Data (1 Site): 7 day ave. of daily max. of 68.0 with 57 days exceeding standard (64°F) in 1994. BLM site in 1996 7 day ave. max. water temperature 67.7°F.
Middle Creek	Mouth to headwaters	Temperature Rearing 64°F (17.8°C) summer	Two BLM sites in 1996, both sites exceeded temperature criteria, 7 day ave. max. was 68.3/69.9°F
Woodward Creek	Mouth to headwaters	Temperature Rearing 64°F (17.8 C) summer	Two BLM sites in 1996, data show exceedence of temperature criteria, 7 day ave. max. at one site 70.0°F and do not show an exceedence at the other was 62.5°F, stream too short to segment.
Coquille River, North Fork	Middle Creek to Little North Fork	Temperature Rearing 64°F (17.8°C) summer	DEQ Data (4 Sites: RM 29.0,32.8,33.9, 47): 7 day ave. of daily max. of 68.7/71.5/67.4/65.8°F with 57/77/31/7 days exceeding standard (64) in 1994; ODFW (2 Sites; RM 39.25, 40.3): 7 day ave. of daily max. of 66.7/64.4°F with 17/7 days exceeding std. in 93.
Coquille River, North Fork	Mouth to Middle Creek	Temperature Rearing 64°F (17.8°C) summer	DEQ Data (3 Sites: Hwy. 42 near mouth, Bennett Park, and Near Hervey Bridge; RM 0.1, 10.2, and 18): 7 day ave. of daily max. of 71.2/75.8°F, nd/71.0°F and nd/70.4°F with 79/96, nd/56, and nd/62 days respectively exceeding temperature standard in 1994.
Coquille River, North Fork	Mouth to Middle Creek	Bacteria Water Contact Recreation (fecal coliform - 1996 Standard) fall-winter-spring	DEQ Data (2 Sites: 402063, 404252; RM 0.2, 4.1): 43% (3 of 7), 0% (0 of 9) FWS values exceeded fecal coliform standard (400) with a maximum value of 1600 between WY 1986 - 1995

Very little data exists regarding the historical or current levels of silt and sand in streams in the watershed. A sediment budget for the adjacent Tioga Subwatershed (Scalici, 1996/1999) does suggest how sediment levels may have changed in recent decades in at least the eastern half of the North Fork Coquille Watershed, given that those two areas have similar management histories and geology. Scalici found formations of bare sandbars during the 1960's suggesting sediment delivery exceeded the stream's capacity to transport sediment. That was a time of considerable road building, cat logging and by today's standards little stream protection combined with a wet cycle. Scalici observed down cutting on the mid 1970s and mid 1980s aerial photos. This may be due to the loss of instream CWD and therefore a loss of the channel's ability to store sediment.

Reference Conditions

We do not have direct measurements documenting water quality in the North Fork Coquille Watershed from before the conversion of bottom lands to farms or the beginning of large-scale timber harvest operations and extensive road building. Variations in water quality, before Euro-American settlement, can be inferred based on the reference conditions and on going processes described in the Erosion Processes Chapter, Vegetation Chapter, and in the Fire History Appendix. Intense storm events and large fires would have caused periods of elevated sediment levels. Stand replacement fires would have also increased exposure of streams to sunlight and by that elevated water temperature.

Shading of major streams in 1950: Aerial photos taken before logging began in earnest in the more remote parts of the Watershed show the canopy closure above streams, and by that indicate the amount of stream shading. Aerial photos are normally taken around the middle of the day in the summer months because that is when the sun is high in the sky. This provides the best illumination and the shortest shadows for aerial photography purposes, and incidently also documents the amount of sunlight that reaches the stream during the hottest part of the day during the summer.

The flood plains next to the 8th, 7th, 6th and lower 5th order reaches were converted to agriculture by the time the 1950 aerial photos were taken. Consequently, the 1950 aerial photos do not show the premanagement conditions for those reaches, with respect to shade. The photos do suggest that the 8th order reach and the wider 7th order reaches may be too wide to be fully shaded by hardwood trees growing on the stream banks and flood plains. Historical accounts suggest myrtles, maples, and in places ash, were the dominant tree species on the flood plains in this part of the Watershed (Vegetation Chapter). The 1950 photos did show the overhead shade increased where the 7th order channel was confined. However, a narrow linear gap above the confined channel reaches showed the canopy closure was not complete.

In 1950, the lowest reach in the Watershed with an intact stand of trees on the flood plain, was a 2,000 foot long 6th order stretch of Middle Creek in section 5, T28S.,R11W. This part of Middle Creek is shown in Figure 1. Here, the flood plain on the east side of Middle Creek supported a hardwood stand with scattered conifers. The upland slope above the west bank of Middle Creek supported a stand with an open conifer overstory, and a well-stocked hardwood understory. The surface of Middle Creek is visible on the aerial photos for most of the 2,000 foot reach. It is unknown how representative this short stretch of riparian forest is of the rest of the 6th order stream reaches. Also damage to the stream bank, caused by log drives between 1902 and the mid-1930s, may have allowed the channel to widen (Farnell 1979).

The 1950 aerial photos showed the 4th and 5th order reaches, which flow through intact late-successional forests, to have myrtle and maple dominated streamside areas. Typical canopy closure ranged from 40% to 70%. However, the canopy closure extremes above the stream channels ranged from 90%, where there were young trees, down to no cover directly above the stream, where debris torrents or channel migration removed stream side trees. Conifer stocking, when present in stream side areas, is generally either sparse or clumpy. The 4th and 5th order reaches are narrow enough to potentially be fully shaded. However, those reaches with flood plains had large canopy gaps attributed to channels migrating across the flood plains recruiting stream bank trees to the channels and by that opening canopy gaps. See figures 2 and 4. The open stand structure (patches and gaps) next to streams that are topographically confined and have little or no flood is likely due to either brush competition preventing trees from becoming established following a severe disturbance, or alders dying from old age leaving understory shrub competition that precluded establishment of understory trees that could have filled the canopy gaps (Newton; Cole 1994; Oliver; Larson 1990; Hemstrom; Logan 1986 and Managing for Landscape Level Diversity Based on Observed disturbance and Stand Development Patterns in the appendix).

Narrow linear gaps were visible above some stream reaches. The narrow linear gap may be the result of alders dying of old age after having occupied the moist toe of the slope next to the stream following the last stand replacement event on the site (Newton; Cole 1994). Alternately, the alders may have regenerated on the stream banks after the channel was scoured by a debris torrent. As the alders decline, more light reaches the forest floor allowing the herb and shrub layers to increase in vigor (Oliver; Larson 1990). Lacking disturbance, a vigorous dense shrub or tall herb layer can prevent understory tree regeneration from becoming established. See figures 2, 3, 5 and 6 for examples.

The difficulty of seeing the surface of some 4th order and smaller streams through large canopy gaps suggests streamside shrubs, in the understory, are important sources of shade along these narrower streams (figure 7).

In general terms, canopy cover was more complete above streams

- With narrow "V" channels than channels with flood plains.
- On south to west aspects than on north to east aspects.
- Higher in the watershed (1st and 2nd order streams) than on lower in the watershed.

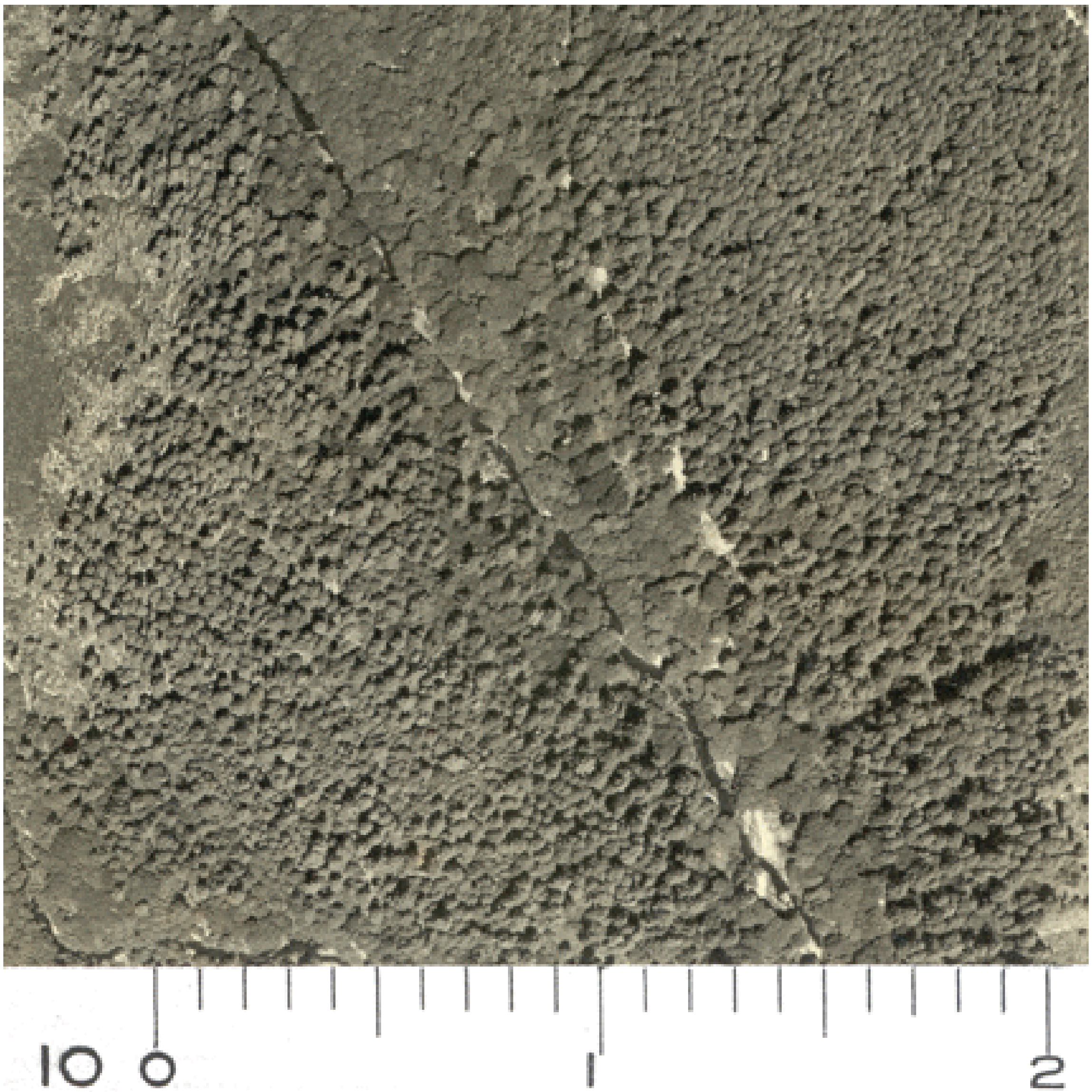

Figure 1: The 1950 aerial photos show an unlogged stream side forest along about 2,000 feet of the 6th reach of Middle Creek where it flows through section 5, T.28S.,R.11W. The rest of land along this reach had been logged or converted agriculture by 1950. The flood plain area east of the stream supported myrtle, bigleaf maple with scattered conifer. Many of those conifers were grand firs. The aerial photo shows a road on the flood plain that has since been abandoned and now grown over. The west bank is against upland that supported an open conifer overstory with a well stocked hardwood understory. The surface of Middle Creek is visible on the aerial photos for most of the 2,000 foot reach. The scale on the south side of the image, shows inches and tenths of inches, and is enlarged the same amount as the aerial photograph. The original photo scale is approximately 1 inch to 1,000 feet. COQ 1950 6-133 (7-26)

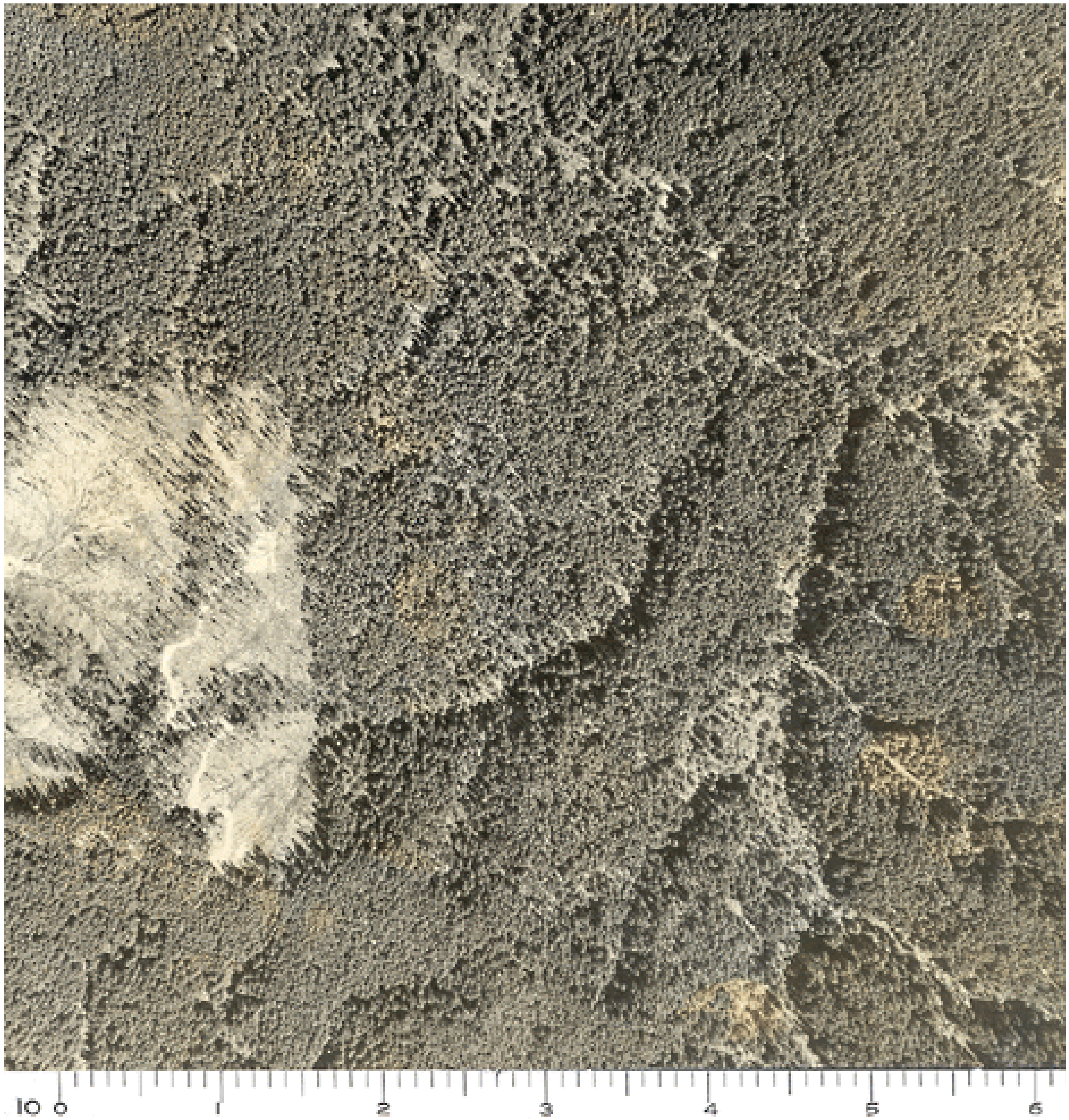

Figure 2: The North Fork Coquille is shown crossing the upper right hand corner of this image and is flowing to the northwest. This segment of the river is in the S½ , section 8, T.26S.,R.10W. In 1950, this was the lowest segment of the river that still flowed though late-successional forest. At the time the photograph was taken, virgin forest extend from this location to the headwalls. The stream side forest consisted of irregular-edged bands of bigleaf maples and myrtles with scattered conifer. The upslope areas were conifer dominated. On short stretches, where conifer dominated stands grew close to the river, the location of the channel is indicated by a 100 foot wide linear gap in the canopy. These linear gaps were possibly the result of channel migration. These gaps may have also been created by streamside alders dying and not being replaced because competitive herbs and shrubs prevented understory trees from becoming established. The channel is visible in these gaps when view under a stereoscope. Tributary 3rd and 4th order streams had similar stream side stands and those channels are also visible in places through canopy gaps. The scale, on the south side of the image, shows inches and tenths of inches, and is enlarged the same amount as the aerial photograph. The canopy closure above the North Fork Coquille ranging from no over head shade to 80% crown closure. The original photo scale was approximately 1 inch to 1,000 feet. COQ 1950 4-9 (11-9).

The harvest unit on the left side of the picture is an example of a seed-tree cut, which was the regeneration harvest method commonly practiced in this watershed during the 1940s.

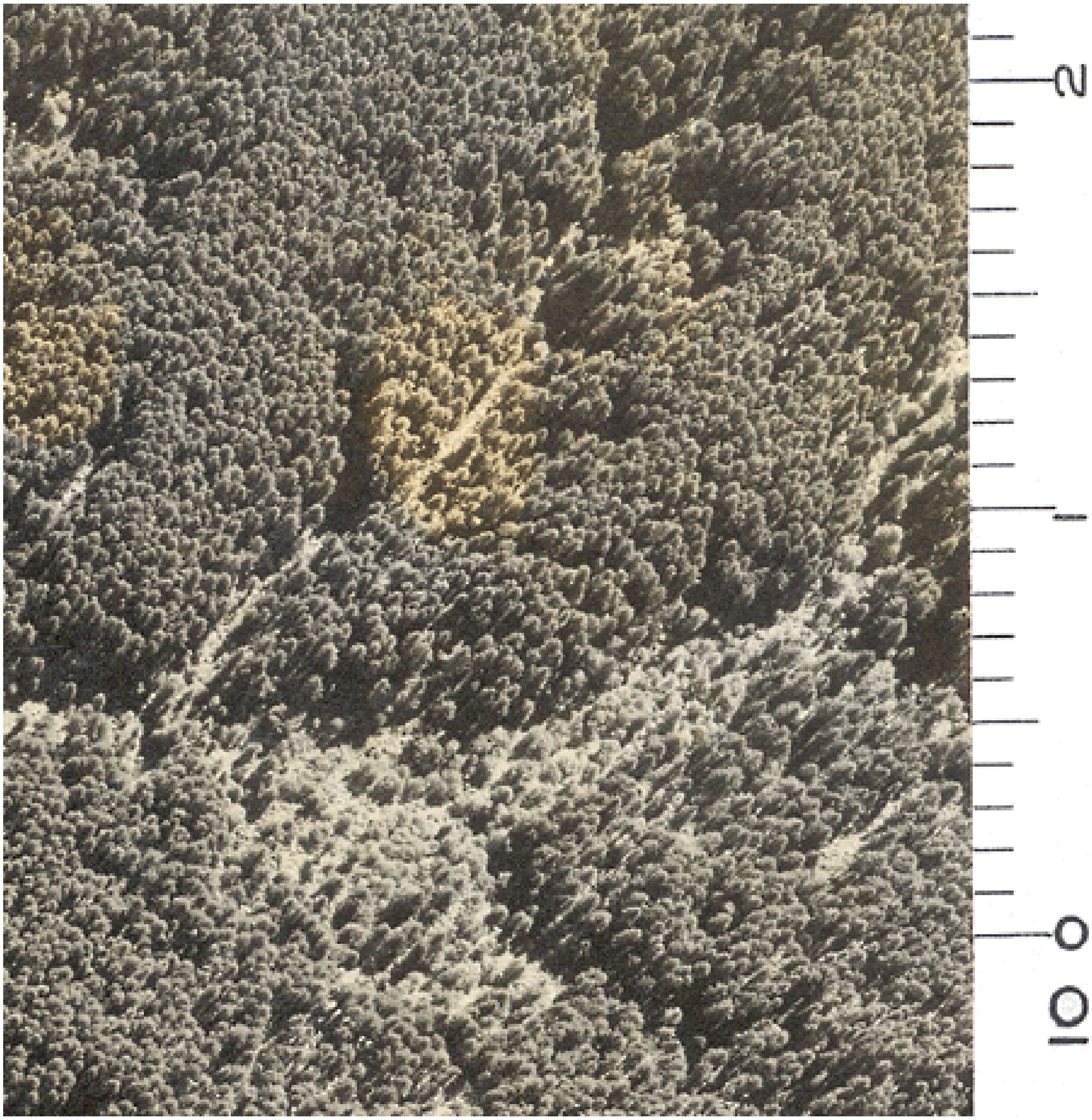

Figure 3: This is an enlargement of the lower of the lower right hand corner of figure 2. The picture is rotated 90° so that the south, and the scale, are on the right side of the image. The north flowing largest stream is 3rd order. The canopy closure of the stream side hardwood dominated stand ranges from 50% to 80% and averages about 70%. The tributary on the east, which flows to the north west, is a 2nd order stream, and the north east flowing stream joining the 3rd order is a 1st order. The linear canopy gap above the 2nd order stream is approximately 50 feet wide. The linear canopy gap is likely either an artifact of a past debris torrent or is the gap left by stream side alders that had grown old and died.

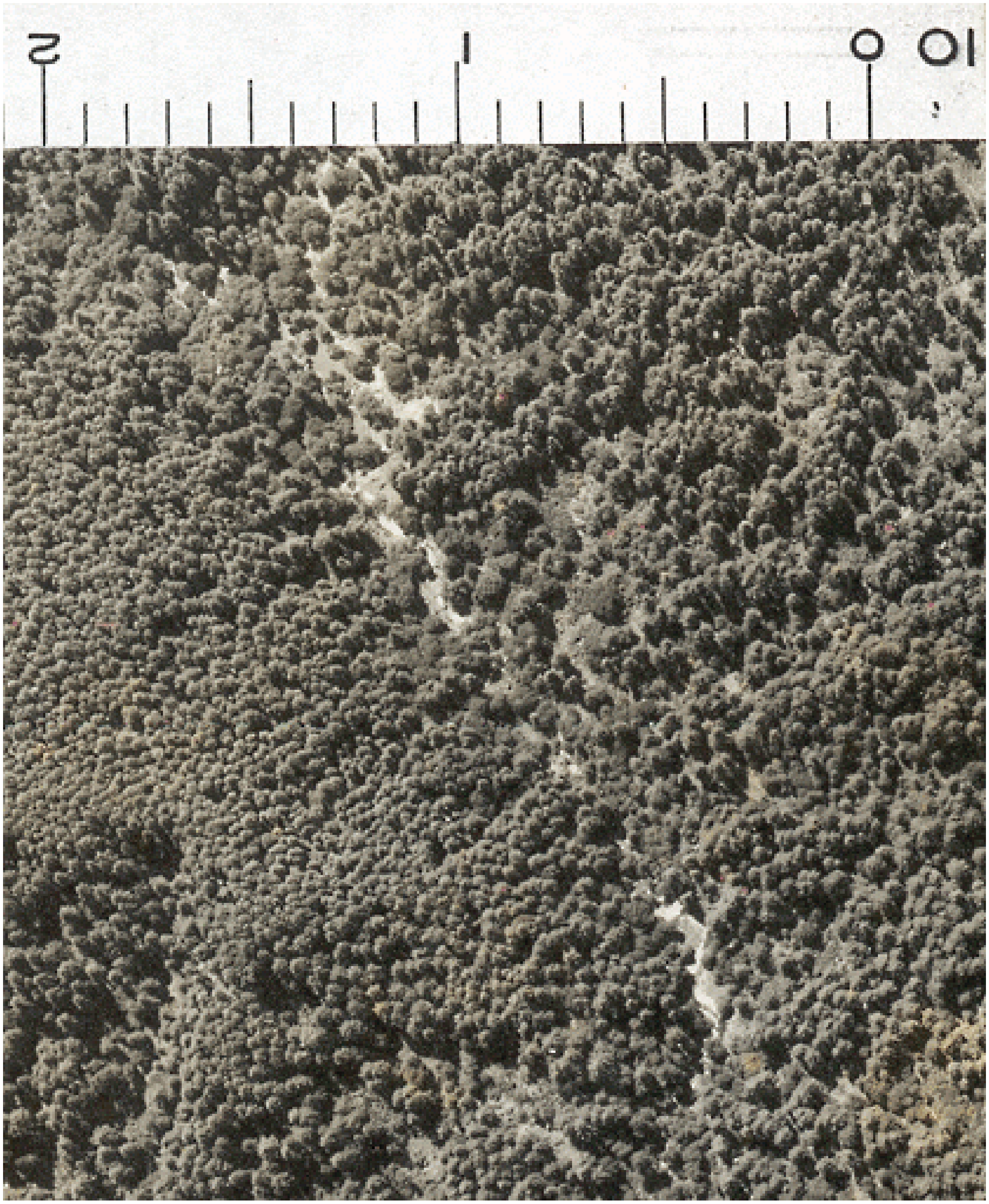

Figure 4: This reach of the North Fork Coquille River is in sections 16 and 21, T.26S.,R10W. The channel and flood plain are visible as a result of the channel migrating across the flood plain and by that recruiting the flood plain trees to the channel. Competition by the herbs and shrubs likely limited tree regeneration following the opening of the canopy. Conifers planted in the 1970s near the location shown in photograph sustained severe elk damage, suggesting heavy elk browsing may have also limited tree regeneration along this reach of the river in 1950 when the aerial photograph was taken. The scale is on the south side of the image. The scale shows inches and tenths of inches, and is enlarged the same amount as the aerial photograph. The scale of the original photograph is approximately 1 inch = 1,000 feet. COQ 1950 8-31 (12-12).

Figure 5: In 1950, the lowest segment of intact late-successional forest on Alder Creek was on the south boundary of section 31, T.26S.,R.10W. The south boundary of section 31 is just past the bottom of this image. Alder Creek is visible in the small flood plain reach in the southwest corner of the picture. Along the 5th order reach, the streamside stands are dominated by myrtles and maples. Some stretches have scattered conifers in the streamside stands. Other stretches have hardwoods only extending 100 feet either side of the creek. Along the 4th order reach of Alder Creek, the canopy closure, in the hardwood dominated streamside stands, ranges from 40% to 70%. For comparison, the upland conifer stands that are well back from stream channels range from 70% to 90% crown closure. The northwest flowing 3rd order tributary, in section 29, T.26S.,R.10W., has a more or less continuous narrow linear canopy gap above it. That linear gap extends on up a 2nd order and then a 1st order draw to a headwall north of the Coos Mountain Lookout. The narrow relatively straight appearance suggests a past debris torrent may be responsible for the canopy gap.

The exposed rocks on the east end of the Alder Creek Drainage indicate shallow soils. Shallow soil depths limit ground water storage. This can limit summer flows and put the drainage at risk for warmer stream temperatures, when compared with a drainage that has greater ground water storage capacity.

The scale, on the south side of the picture, shows inches and tenths of inches, and is enlarged the same amount as the aerial photograph. The scale of the original aerial photograph is approximately 1 inch to 1,000 feet. COQ 1950 4-14 (11-4).

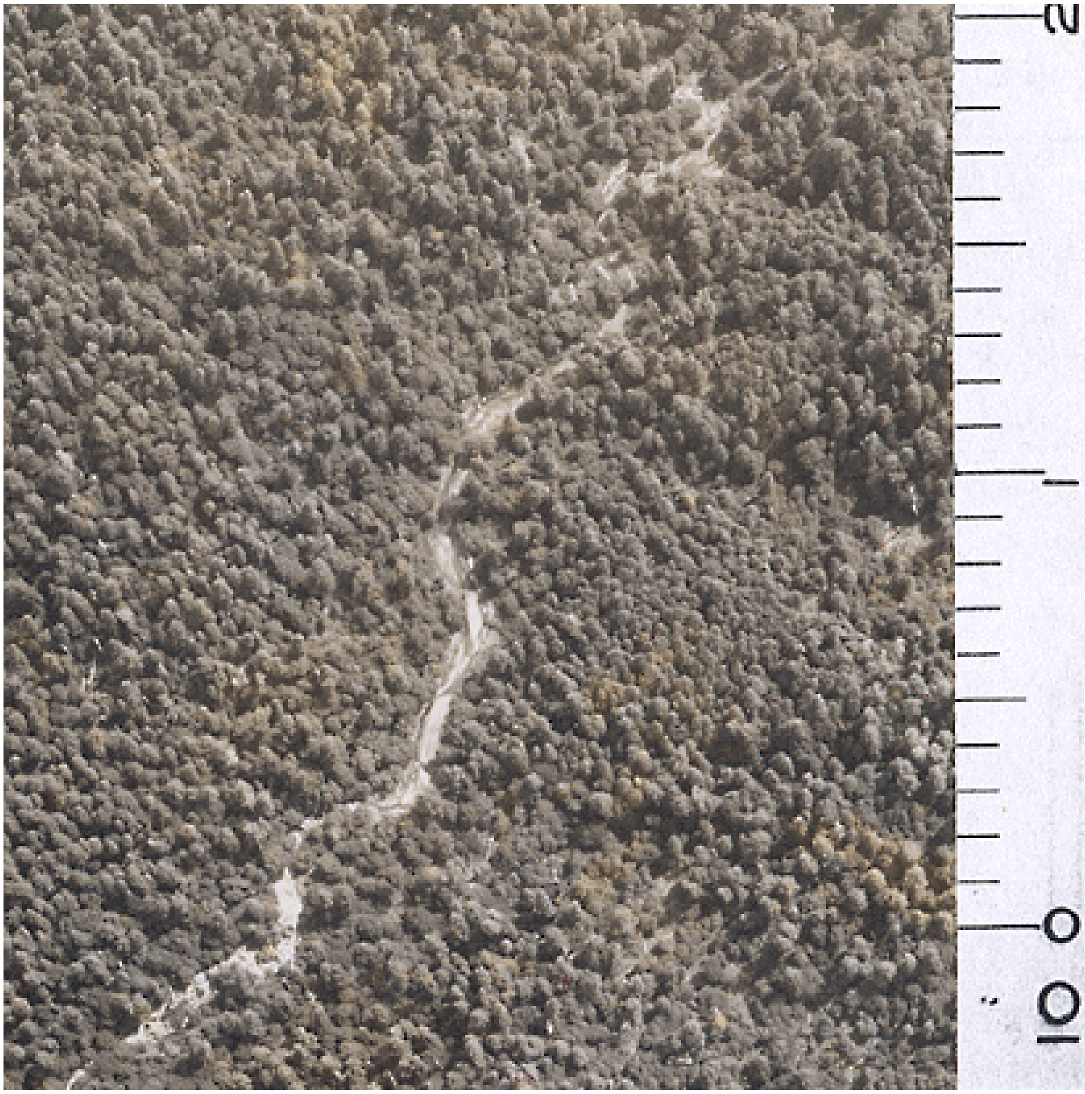

Figure 6: Aerial photos taken in 1943 and in the 1950s showed debris torrents to be a regular disturbance in the Park Creek Drainage. Some of these debris torrents ran for a mile and more. This 1950 photograph shows the Park Creek channel and flood plain after a debris torrent. The severity of the debris torrents favors red alder over other tree species. Debris torrents reoccurring after periods of about 100 years or less maintain red alder on these sites. Red alder's abundant light wind-disseminated seeds, rapid juvenile growth, and capacity to fix nitrogen gives the species a competitive advantage for taking over severely disturbed moist sites. The scale is on the south side of the image. The scale shows inches and tenths of inches, and is enlarged the same amount as the aerial photograph. The scale of the original aerial photograph is 1 inch to 1,000 feet. COQ 1950 8-38 (12-19).

Figure 7: In 1950, the lowest segment of the 5th order reach of Cherry Creek with an intact late-successional forest on both sides of the channel passed through the NE ¼, section 23, T.27S.,R.11W. The stream side areas area dominated by myrtle and bigleaf maple with scattered conifer. Most of these conifers are western redcedar and western hemlock. Douglas-fir is not common within 100 feet of the 4th and 5th order channels. Gaps in the hardwood canopy show the forest floor in several locations along the draw, however, Cherry Creek is not readily visible in the 1950 aerial photos. This suggests the shrub layer is providing at least some over head shade for the 4th and 5th order channels. North Fork Cherry and South Fork Cherry Creeks are on the east side of the photograph, and are the two 4th order streams that join to form the 5th order reach of Cherry Creek. The 4th order stream reaches, are similar to the 5th order reach in being hardwood dominated, with scattered conifers, and gaps showing the forest floor. Canopy closure, within 100 feet of the 4th and 5th order channels, generally ranges from 60% to 70% with small patches of young trees approaching 90% crown closure, and with 200 to 600 foot long reaches having as little as 30% crown closure. Many north flowing 1st order draws have narrow linear canopy gaps above them, whereas the south flowing 1st order draws tend to have a patchy canopy over head. The scale on the south side of the image was enlarged the same amount as the photograph. The scale is in inches and tenths of inches. The original aerial photograph scale is approximately 1 inch to 1,000 feet. COQ 1950 11-67 (10-20).

Synthesis and Interpretation

Water quality overview: Most research on how forest management affects water resources is from observations of practices that were in common use in the 1960s and 1970s (Adams; Ringer 1994). These practices include sidecast road construction on unstable sites, hot broadcast burning that consumed all duff on the site, logging down to the stream edge, and removing or burning woody debris found in the streams. Our technology, practices and standards have changed much since then, in no small part because of that research. In fact, several aspects of Federal land management under the Northwest Forest Plan, with its emphases on large reserves, and confinement of many practices to ridge top locations, are a direct outcome of that research. In addition, using best management practices (BMP) can largely avoid serious degradation of water quality by forest practices (Binkley; Brown 1993). BMPs are incorporated into the Coos Bay District ROD/RMP (USDI 1995: pg. 13, 25, 31, 70, 81 & Appendix D). Therefore, the reader is cautioned to consider the cited research in context of the time the data was collected and in light of current practices.

Water temperature: Elevated stream temperatures are primarily due to a lack of stream shading, a high width to depth ratio and/or low summer flows (Moore & Miner, 1997). A lack of shade allows solar radiation to reach the stream surface. A high width/depth ratio allows more surface area to be impacted by solar radiation per volume of water. Lower flows or volumes contribute to elevated stream temperatures since the change produced by a given amount of heat is inversely proportional to the volume of water heated. Some reaches of the affected streams in the Watershed are subject to all these conditions.

Streams in southwestern Oregon are known for their relatively high summertime temperatures, but it is not clear whether this is related to a latitudinal gradient, high solar radiation loads, low flows, or other related factors (Beschta *et al.* 1987). The primary concern with water temperature increases is the potential for detrimental affects on fish and other aquatic organisms. Climate, solar intensity, channel orientation, and elevation influence water temperature. These factors are generally static and unaffected by human activity. Shade and groundwater are also natural factors affecting water temperature. However, these can be influenced by management activities. Water temperatures of larger streams can also increase when clearcutting exposes small tributaries. Shading on the downstream reaches do not significantly lower the water temperature of streams warmed as the result of loss of shade on upstream reaches (Brown 1970). The amount of daily temperature fluctuation is primarily a response to the daily weather patterns. Maximum temperatures normally occur in the late afternoon and minimum temperatures occur just before dawn. Heat added to a stream is not readily dissipated and when temperature increases in headwater streams occur, downstream reaches can also increase in temperature. The heat balance of water in natural systems is regulated by stream flow, water velocity, stream width to depth ratios, and streamside vegetative canopy cover. Solar radiation is the primary factor causing elevated stream temperatures in the summer, and is largely affected by the degree of interception of this radiation by riparian vegetation (Beschta, *et al.* 1987).

Increases in stream temperature, in response to increased exposure to sunlight, are inversely proportional to stream volume. Therefore during the summer low flow period, small shallow perennial streams can experience a significant temperature increase following a stand replacement event, like clearcutting or high severity fire (Brown & Krygier 1970). However, surviving vegetation next to small streams and wood debris above the channel can have a moderating influence on stream temperatures follow a stand replacement disturbance. In a study on the H. J. Andrews, Levno & Rothacher (1969 cited in Adams & Ringer 1994) found clearcut logging increased maximum water temperature by 4°F. Subsequent slash burning and stream cleaning increased the maximum water temperature an additional 8-10°F. Following a stand replacement disturbance, riparian vegetation regrowth along small streams (about 10 feet wide) will provide shade levels equivalent to mature stands in 10 years (Summers 1982 cited in Skaugset 1992).

Another study showed 50% of a Coast Range stream shaded within 5 years of harvesting and burning (Beschta *et al.* 1987). One study showed the relation between the timber volume left per foot of stream and the amount of heat blocked by that buffer is poor. Angular canopy density correlated well with stream temperature control. The angular canopy density is measured for the solar angle during the minimum flow period. For streams in that study, the maximum angular canopy density (maximum shading ability) was reached within an 80-foot width, with 90% of maximum reached in within 55-feet (Brazier; Brown 1973). Brazier and Brown noted that adding additional angular canopy density provides no additional protection, once the maximum angular canopy density is reached. Brazier and Brown also noted that defuse radiation is controlled by factors other than canopy density. The volume of vegetation in the canopy also influences light transmitted. The thicker canopies provided by conifers are more efficient interceptors of radiation than the canopies of hardwoods even when the canopy densities are the same.

Direct solar heating of streams that are too wide to shaded by overhead trees can, in some cases, result in summer time stream temperatures exceeding 64°F even in relatively untouched watersheds (Brown *et al.* 1971). Riparian shade is unlikely to have a significant influence on stream temperatures where the natural low flow stream width exceeds 100 feet (Washington Forest Practice Board 1992). Conditions on non-fish bearing streams can influence water quality in fish-bearing streams. Brown and co-authors (1971) observed the influence of a tributary's water temperature on a stream is proportional to its discharge. For example, non-fish-bearing tributaries contributing 20% of the flow to a fish-bearing stream will significantly influence water temperature (Caldwell *et al.* 1991 cited in Washington Forest Practice Board 1992). Therefore activities on tributary streams to retain or obtain streamside shade, and to improve contact and exchange between water in the stream channel and ground water (retain deep gravel beds, and reconnect streams with their flood plains) can insure cool water enters the fish bearing tributaries and the main stem streams.

Stands in the stem exclusion stage of stand development produce the maximum amount of shade obtainable from trees (Oliver; Larson, 1990). The stem exclusion stage generally begins about age 15 or 20 and lasts at least to age 50 in the Watershed. The duration of the stem exclusion appears longer in stands with high proportion of western hemlock. Deciduous hardwoods canopies allow more defused light to reach the forest floor than conifers resulting in shorter stem exclusion periods for hardwood dominated stands. Stands can be manipulated either to shorten or to extend the stem exclusion stage. However, maximizing shade and extending the stem exclusion stage period may maximize attainment of cool stream temperatures, doing so can delay attainment of late-successional forest characteristics and delay attainment of benefits provided by stream side forests to aquatic systems. These delayed benefits include:

- A greater variety litter and arthropod input to the stream from multi-species, multi-layered stands compared with the input from the simpler-structured stem exclusion stage stands.
- More rapid attainment of large trees that can provide large wood debris to the channels and flood plains.
- Multiple canopies that provide redundant sources of shade. In the event that blowdown opens the overstory tree canopy, the stream still benefits from shade provided by understory trees and the shrub layer. In contrast, blowdown in a stem exclusion stage stand removes all overhead live shade.
- Multi-species stands provide redundant sources of root strength to resist surface erosion and provide stream bank stability. Here again, a blowdown event in a stem exclusion stage stand removes nearly all sources of live roots, whereas the multi-layered multi-species stands associated with more open stands have live roots of understory trees, shrubs and herbs providing stream bank stability in the event the overstory trees are lost.

The 1950 aerial photographs of 4th and 5th order streams flowing through late-successional forest indicate the stream side trees generally did not provide the maximum level of shade associated with stands in the stem exclusion stage of stand development. The photos did show the canopy closure above 4th and 5th order streams generally to range from 40% to 70%. While this is less than maximum potential shading, these conditions did allow for development of the late-successional characteristics and benefits outlined above. The findings here are consistent with the results of the coarse wood debris recruitment potential analysis summarized in the Vegetation Chapter. The coarse wood debris analysis consider stand composition and density within 100 feet of all streams whereas the assessment of overhead shading considered the canopy characteristics in a more restricted zone immediately above 4th and 5th order stream channels and flood plains. The shift from open or moderately-stocked hardwood-dominated conditions immediately above channels to the 75% and denser stocked conifer or hardwood stands back from channels occurs over short distances. This is particularly true on 3rd order and smaller draws and on south to west aspects.

Riparian zone surveys along north and central Oregon coast streams, which were neither subjected to logging nor farming found the near-stream (averaging more than 30-feet) plant community was nearly treeless 52% of the time. Hardwoods were dominant 28% of the time. All the stream-side stands were subject to a stand replacement fires 150-years earlier and therefore had gone through 150-years of successional change. The treeless areas may have initially been dominated by red alders, which had died of old-age. Alternately, beavers may have denuded these areas or these areas may have failed to support successful tree regeneration (Emmingham; Hibbs 1997).

The Density Management and Conversion Treatments and Attaining Riparian Reserve Function chapter in this document contains additional discussion on water temperature as influenced by stream side shade.

Sediment: Sediment deposition is the process most directly related to impacts to water quality. Excessive fine sediments cloud water, choke fish gills, blanket fish spawning areas, smother bottom-dwelling aquatic organisms, and downstream can fill navigation channels and may alter estuary processes. According to MacDonald (1991), “An increased sediment load is often the most important adverse effect of forest management activities on streams.” Some amount of fine sediment is necessary for channel development and for providing habitats to some aquatic organisms. The larger material such as gravel, cobble and wood provide the components necessary for creating complex habitats.

Site conditions (soil type, slope, and geology), road location and construction standards, and site prep intensity have more affect in sediment delivery than soil disturbance caused by logging. The use of BMPs generally minimizes suspended sediment concentrations, though often at a substantial cost (Brazier; Brown 1973). Sources of sediment from surface erosion are soils exposed by broadcast burning, and along roads and landings (Beschta 1978). Beschta also noted in the Alsea Study that high-lead cable logging, light broadcast burning (in contrast to extremely hot burns) had little affect on sedimentation, and the retention of stream side buffers protected stream beds and banks from damage by yarding activities.

Sediment from road failure was considered the greatest water quality problem, according to a study by Brown (1972b cited in Adams; Ringer 1994). In that same study, erosion of soils exposed by severe slash burning on steep slopes was often the principle cause of surface erosion. The former problem is avoided by confining roads to stable soils and ridge top locations, locating roads away from streams, timely road and culvert maintenance, using specially designed cable logging systems in place of building mid-slope roads, and by using construction techniques like end-hauling and full bench construction when building on fragile land is unavoidable. High-lead logging alone did not produce significant amounts of sediment where it was studied on Coast Range sites (Brown; Krygier 1971). In another study involving both Cascade and Coast Range sites, Landsliding from forest roads was the most important source of increased stream sedimentation, whereas soil disturbance caused by logging operations resulted in no detectable increase in stream sedimentation (Fredriksen *et al.* 1973 cited in Adams; Ringer 1994). Surface erosion associated with burning is minimized by using burning under conditions that allow retention of the duff layer or by employing alternative site prep treatments that do not involve exposing bare mineral soils on steep sites (Brown 1972a&b cited in Adams; Ringer 1994; USDI 1995 Appendix D).

Sediment associated processes, and interactions are discussed at length in the Erosion Processes chapter.

Bacteria: Elevated bacteria levels likely are associated with grazing livestock, and substandard septic systems in stream side areas.

Flow Modification: Modification of peak and low flow is covered in the Hydrology chapter.

Habitat Modification: Removing large wood, eliminating or limiting large wood recruitment, confining stream systems and modifying the existing flood plains has simplified the aquatic ecosystems and altered channel characteristics. These issues are discussed more fully in other chapters.

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